CALIFORNIA
ENERGY
COMMISSION

California Hydropower System: Energy and Environment

Appendix D
2003 Environmental Performance Report

DRAFT STAFF REPORT

Prepared in Support of the *Electricity and Natural Gas Report* under the Integrated Energy Policy Report Proceeding (02-IEP-01)

AUGUST 2003
100-03-018SD

Gray Davis, *Governor*

CALIFORNIA ENERGY COMMISSION

Jim McKinney
Author

Matthew Layton
Stuart Itoga
Contributors

Jim McKinney
Kevin Kennedy
Project Managers
2003 Environmental Performance Report

Al Alvarado
Project Manager
ELECTRICITY AND NATURAL GAS REPORT

Karen Griffin
Program Manager
INTEGRATED ENERGY POLICY REPORT

Dave Maul
Manager
NATURAL GAS AND SPECIAL PROJECTS OFFICE

Terrence O'Brien
Deputy Director
SYSTEMS ASSESSMENT AND FACILITIES SITING DIVISION

Robert L. Therkelsen
Executive Director

Table of Contents

List of Figures

List of Tables

California Hydropower System: Energy and Environment

Opportunities to Improve Environmental Quality in California's Hydropower System While Maintaining the Positive Attributes of Hydroelectricity

This special focus section of the ***2003 Environmental Performance Report*** examines the relationship between California hydroelectricity production and environmental quality. The Energy Commission added this area of inquiry to the Integrated Energy Policy Report (IEPR) in response to the California Resources Agency's request during the IEPR scoping phase. The Resources Agency posed three questions:

1. Given the current surge in hydropower relicensing, "to what extent can instream flows in different river reaches be increased without severely compromising energy production or economics?"

2. "Are the economics of hydroelectric operation, management and licensing substantially different than for other power generation technologies?" and

3. Given that "restoration of California's endangered salmon and steelhead trout is an important policy goal … is it appropriate to assume that select hydropower projects and dams can be eliminated or diminished without jeopardizing electricity supply reliability or cost?" (Resources Agency 2002)

This section compiles information presented by Energy Commission staff, sister government agencies, hydroelectric producers, and environmental organizations at the June 5, 2003 IEPR Workshop "Hydropower System – Energy and Environment." This section provides summaries of the hydropower system environmental effects identified in the 2001 and 2003 Environmental Performance Reports. It also presents the results of Energy Commission staff investigations on systems level environmental effects of hydropower development and operations, energy changes associated with recent Federal Energy Regulatory Commission relicensing cases in California, the costs of hydropower production and relicensing, and assessments of the energy effects of three proposed decommissioning / repowering projects in California.

Summary of Findings

Selective Mitigation and Restoration of Rivers Can Be Achieved with Minimal Effect on Energy Values: Substantial opportunities exist to improve environmental quality in California watersheds that have been degraded or impaired from hydropower development and operations. In some instances, significant improvements in environmental quality may be achievable with relatively small losses in energy values. Recent reviews by Energy Commission staff of restoration proposals and relicensing cases have indicated that mitigation, enhancement and restoration can be achieved in these instances with no appreciable effect at the statewide level on electric system reliability. While restoration opportunities are likely to exist that have no appreciable diminishment of hydropower's important energy values to the California grid and electricity market, each case needs to be carefully evaluated to assess possible local and regional effects on reliability and cost.

Hydropower Energy Values: Hydroelectricity is an important element of California's energy portfolio. Between 1983 and 2001, in-state hydropower provided an annual average of 37,345 GWh, or 15 percent, of the electricity used in California. During this same period, hydroelectric generation ranged from 9 percent to 30 percent of total state electricity sales, depending on hydrologic conditions. Hydropower's important energy attributes include peaking reserve capacity, spinning reserve capacity, load following capacity, transmission support, and extremely low production costs.

Hydropower's Changing Role in System Reliability: The electric system's reliability and capacity to respond to peak demands and load swings is increasingly borne by the natural gas-fired sector and imports. Hydropower's once unique role in providing critical peak demand resources is diminishing due to increases in electricity production from combustion turbine peakers and advances in energy efficiency and demand side management measures. Thermally and environmentally efficient combined cycle central station power plants are providing increasing amounts of baseload energy and capacity.

Hydropower and Air Emissions: Hydropower does not create the air emissions associated with thermal power generation, including NOx, greenhouse gases, and particulate matter.

Hydropower Creates Significant, Ongoing Environmental Impacts: Hydropower production creates significant, ongoing impacts to many California rivers and streams, native wild salmon and trout populations, and the water quality needed to support sustainable riverine ecosystems. Thousands of miles of stream and river habitat cannot support sustainable populations of native wild salmon, trout, amphibians and other aquatic species. The majority of the state's hydropower projects were licensed by the Federal Energy Regulatory Commission (FERC) 30 or more years ago, and so were not subject to current environmental standards. A key indicator for conformance with state environmental standards is the Section 401 Clean Water Act Certification for waste discharges. While numerous hydropower projects received certifications or waivers of the certification requirement in previous decades, only nine of 119 FERC-licensed projects meet or will soon meet current State of California water quality standards, as reflected in Section 401 Certifications issued by the California State Water Resources Control Board.

New Renewable Resources: The California Renewable Portfolio Standard will spur increases in renewable energy resources such as wind, geothermal, biomass, photovoltaics and other emerging technologies. Such technologies do not degrade riverine ecosystems, although they can create other environmental impacts. Such new technologies tend to have higher costs than existing hydropower, and do not contribute to increasing peak reserve capacities as effectively as hydropower.

Relicensing and Selective Decommissioning Have Not Impacted Electricity System Reliability: Based upon reviews of three recent decommissioning proposals and relicensing cases, the Energy Commission staff has found that impacts to statewide electricity system reliability from the decommissioning proposals and hydroelectric project reoperations that were studied would not be significant. Staff's review of 14 recent relicensing cases in California with a total of 567 MW capacity identify an energy production decrease of 5.26 percent (147 GWh) as a result of FERC-ordered mitigation measures. Staff's review of three proposed decommissioning or reoperations projects to restore California salmon populations (Battle Creek, Trinity River Diversion and Klamath) identify a combined potential energy production loss of 1,041 GWh, or 2.7 percent of the state's total annual hydroelectricity production 37,345 GWh. Specific decommissioning proposals would need to be fully evaluated on a case by case basis to identity potential local area reliability effects. Energy Commission staff recognize that electricity system reliability effects are just one of many factors that need to be evaluated when decommissioning is recommended as a potential restoration method.

Introduction

The balance between hydroelectricity production and environmental quality is evolving as societal views and scientific understanding of the relative benefits and impacts of hydropower production change. Freshwater riverine and stream ecosystems are critical elements of biodiversity and biological productivity in the arid West. Scientists are finding that the aquatic ecosystems of California rivers and streams are among the most imperiled and ecologically stressed habitats in California (UC Davis 1996, Mount 1995, Moyle et al, 1998, Moyle and Davis 2000, Allan and Flecker 1993). Concurrently, electricity demand growth, changes in power system technologies, pollution control technologies, and economics have spurred the development of natural gas-fired power plants that meet increasingly large portions of peak and load following electricity demands. Combined cycle and combustion turbine power plants are extremely efficient and flexible power generation resources.

In addition, the electricity generation system has evolved into a highly integrated mix of resources that is dispatched and shared throughout the Western United States, Canada and Mexico. It is a diverse system of regulated and merchant producers that has little resemblance to the vertically integrated utility systems that once characterized electricity production, transmission and distribution within separate utility service territories. The new electricity markets are nearly virtual in that they are based on contracting between multiple consumers, aggregators, load serving entities, investor-owned utilities and municipal utilities, all coordinated through independent system operators that control electricity dispatch for large regions of California and the Western United States. Natural gas fired generation units are regularly cycled up and down to meet load, which means that changes in electricity production from specific units can often be readily replaced from units throughout the West that are linked to the grid through contracts and transmission lines.

California has numerous hydropower projects with small amounts of capacity and relatively low energy values – low production levels and little to no dispatchable energy from reservoirs – that cause disproportionate amounts of environmental damage because they directly affect salmonid bearing rivers and streams. Analyzing these low value – high impact hydropower projects may reveal that substantial restoration benefits can be achieved with only minimal effects on energy system reliability and costs.

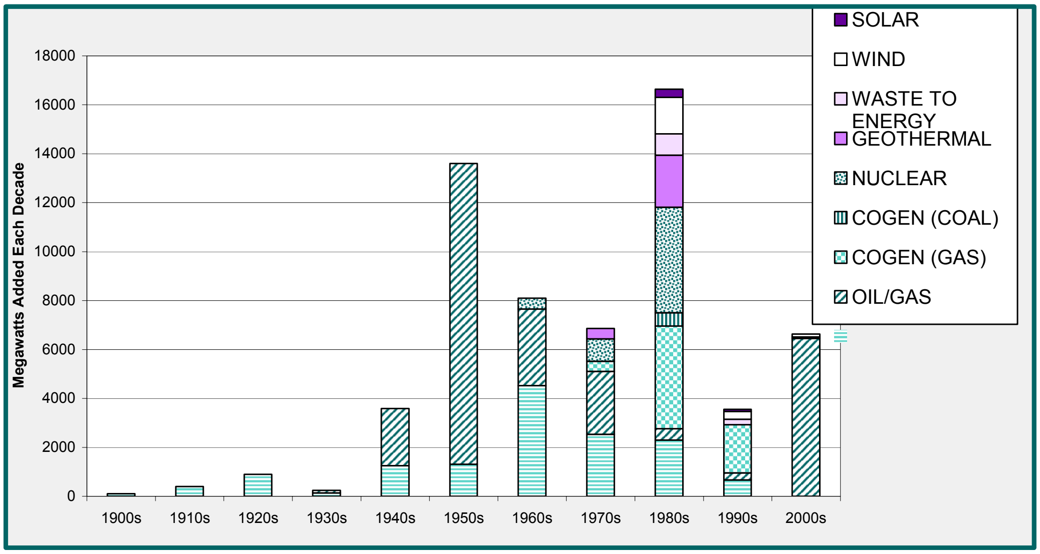
Hydropower's Role in California Electricity System Reliability

California has 14,116 MW of hydropower capacity at its disposal, which represents about 25 percent of California's 55,800 MW of electricity production capacity. Investor-owned utilities, municipal utilities and irrigation districts account for about 9,100 MW of this capacity, while the state and federal water projects have about 3,900 MW. **Table D-1** shows ownership of California hydropower in more detail. California's hydropower system is the nation's second largest after Washington State's. The Pacific Coast states of California, Oregon and Washington account for nearly 50 percent of the nation's total hydropower capacity.

Hydroelectricity is an important element of California's energy portfolio. Between 1983 and 2001, in-state hydropower provided an annual average of 37,345 GWh, or 15 percent, of the electricity used in California. During this same period, hydroelectric generation ranged from 9 percent to 30 percent of total state electricity sales, depending on hydrologic conditions. Hydropower's important energy attributes include peaking reserve capacity, load following capacity, extremely low production costs, and near-zero air emissions.

Figure D-1 illustrates the development of hydropower in relation to other generation resources over the past 100 years. Early in the 20th century, abundant hydrological resources were the main sources of electricity. Hydroelectric development has continued in all decades throughout the century, peaking in the 1960s. Substantial hydroelectric pumped storage capacity was added from the late 1960s to the early 1980s. Today, most of the cost-effective, environmentally appropriate sites for hydropower projects have already been developed. About 61 percent of the current hydropower system (8,619 MW), was built prior to the enactment of the major environmental statutes in the 1970s.

Figure D-1
California Generation Capacity Additions



Source: 2003 Environmental Performance Report Figure 2-1.

California hydropower is a broad network of small and medium-sized projects distributed widely throughout the state's watersheds. There are 386 hydroelectric generating units recorded in the Energy Commission database ranging from 0.1 MW to over 1,000 MW in size. On rivers like the Feather, Pit, American, Mokelumne, Stanislaus, San Joaquin and others, multiple powerhouses of one to two hundred MW are linked and operated as unified systems totaling 700 MW and greater. The rest of California's hydropower system is an amalgamation of small and mid-sized projects distributed throughout the state. Some of these more disparate projects provide relatively low value energy supplies in that they are run of the river projects or have modest storage and dispatch capacity.

Investor owned utilities (IOUs) own and operate about one third of California's 14,116 MW hydropower system. Municipal utilities, irrigation districts and water districts also operate about one third of the system, while the state and federal water projects have one fourth of the capacity. Major ownership is shown on the following table.

Table D-1
Major Hydropower Ownership in California

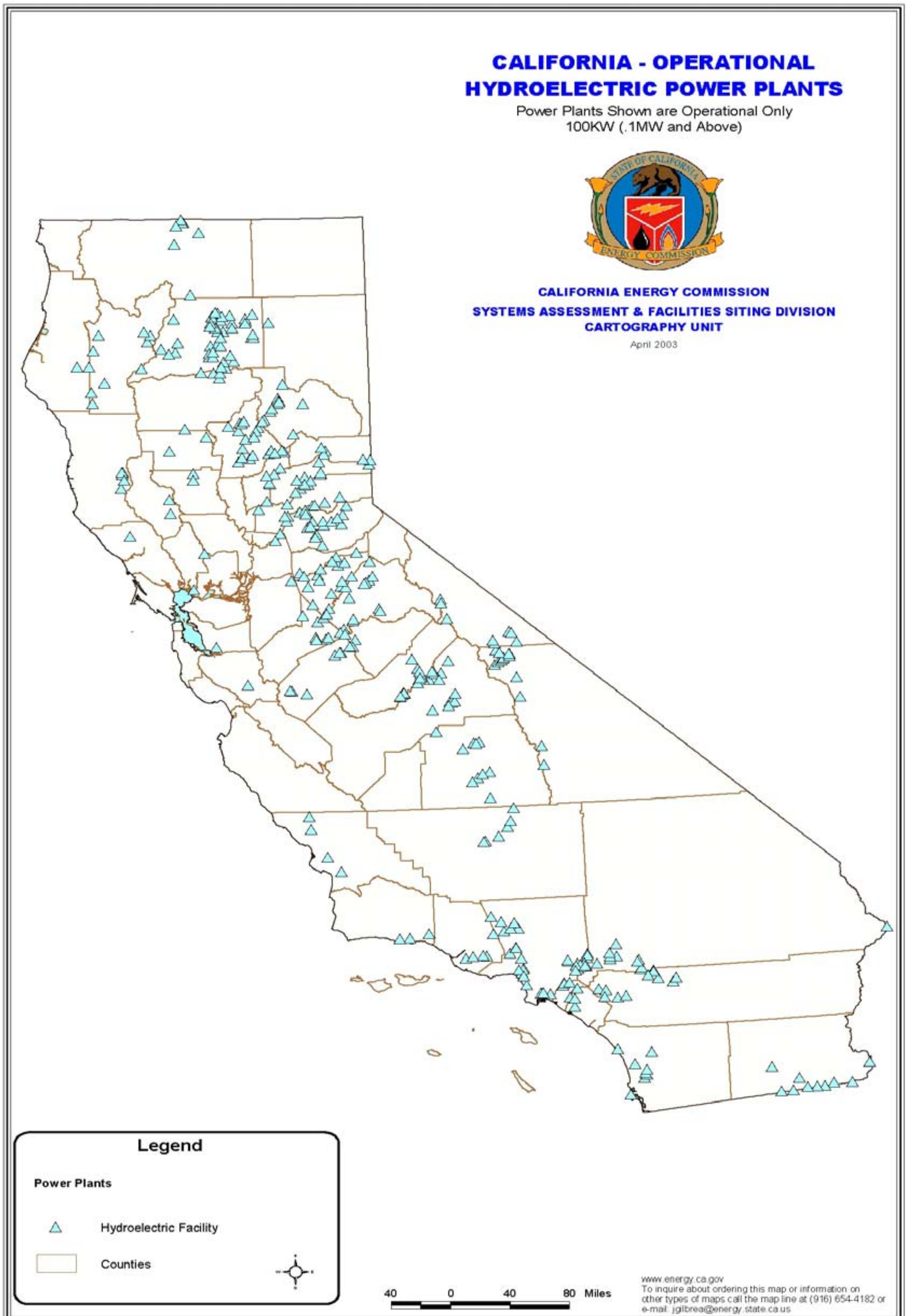
Owner Type	Owner	Capacity (MW)
IOUs	PG&E	3,896
	SCE	1,163
Water Projects	USBR – Central Valley Project	2,355
	DWR – State Water Project	1,520
Municipal Utilities	Los Angeles DWP	1,761
	Sacramento MUD	688
	San Francisco PUC	385
	Other Municipal Utilities	513
Water Districts		921
Irrigation Districts		704

Note: Table delineates major ownerships only, and does not total 14,116 MW
Source: California Energy Commission Power Plant Database

Most dams with hydroelectric generation capacity serve multiple purposes that include power generation, water supply and flood control. Generally, IOU hydropower projects' primary purpose is power generation, while ancillary water supply, flood control and recreation benefits are also created. This means that power generation is the primary consideration for project operations, and is scheduled to meet load. For the state and federal water projects, the primary purposes are water supply and flood control, while ancillary power generation and recreation benefits are created. The state water project is a net consumer of electricity, while the federal water project is a net generator of electricity. Both state and federal projects generate power as water is distributed throughout the system. For municipal utilities, water and irrigation districts, varying combinations of hydropower, water supply or flood control may be the primary project purposes, while recreation and other purposes are important ancillary benefits. Hydropower revenues can be an important part of municipal utility operations.

Geographically, the IOU hydro projects tend to be higher in the Sierra and Cascade watersheds. The rest of California hydropower is part of the water supply and flood control systems, and tends to be located in the lower foothill elevations. **Figure D-2** shows the geographic distribution of California's hydropower facilities.

Figure D-2
Geographic Distribution of California Hydropower Facilities



California hydropower can be broken into three main categories; storage, pumped storage, and run-of-the-river. Storage and pumped storage are the most valuable because of their peaking reserve capacity attributes and dispatchability. Their energy potential can be saved and used to meet peak and needle peak load demands on hot summer days when air conditioning loads are highest. Storage and pumped storage hydropower provide a critical function in meeting peak demands and maintaining system reliability. California has a number of pumped storage facilities, the 1,212 MW Helms Project owned by PG&E, the 1,175 MW Castaic Project which is part of the Los Angeles Department of Water and Power system and three smaller projects owned by the Department of Water Resources; San Luis (324 MW), Edward C. Hyatt (643 MW), and Thermalito (115 MW). Helms is operated as a "true" pumped storage plant in that power is generated to meet peak demand. Castaic is more of an "opportunistic" plant in that power is generated as part of water delivery operations.

Storage plants are the classic hydropower facility. Water is stored in reservoirs of varying sizes and the water is released through the turbines to meet demand. Storage plants typically generate energy throughout the spring snowmelt or runoff season, and then through the summer until minimum reservoir pool levels are reached. Reservoirs help hedge against year to year variance in snowfall by allowing operators to reserve water from one year to the next. California hydropower is distinguished by many low-volume, high head plants that produce large amounts of energy with relatively small amounts of water. Water is channeled from high elevation reservoirs down steep penstocks over vertical drops of hundreds of feet into powerhouses with pelton wheels or Kaplan turbines. This system is quite different from the low head, high capacity run of the river systems that typify hydropower in the Pacific Northwest.

Run-of-the-river production is the type of hydropower that varies the most on a year to year basis. Hydroelectricity production from these units varies in direct proportion to annual hydrology. It is an extremely low cost baseload energy resource that is available when water is available to drive the turbines. The highest run-of-the-river production occurs during spring snowpack melt and run-off.

The Energy Commission is compiling a comprehensive database of California hydropower facilities. When complete, the database will include a delineation of storage and run of the river hydropower projects.

Examples of Hydropower Roles in Generation System Portfolios

At the June 5, 2003 Hydro Workshop, several operators and producers discussed how hydropower fits into their generation system portfolios.

- **California Independent System Operator (CAISO)**

  Hydropower provides about 22 percent of the capacity requirements for the CAISO control area during seasonal peaks. The hydroelectric resources available to the CAISO include 8,470 MW of capacity with about 6,000 MW available for dependable capacity during system peaks. Another 2,760 MW of pumped storage capacity is available, plus 626 MW from the Hoover Dam.

  Hydro imports from the Pacific Northwest add another 4,000 to 7,000 MW of power on high load days.

  Hydro is an important contributor to meeting the spinning reserve requirements operating reserves (three to four percent of total load during all hours).

- **Pacific Gas and Electric Company (PG&E)**

  PG&E owns and operates the nation's largest privately held hydropower system. It has 3,896 MW capacity, and includes 68 powerhouses, 110 generating units, and 99 reservoirs with 2.3 million acre-feet of storage capacity. The system includes 26 FERC-licensed project and three non-licensed projects.

  On an average annual energy basis, PG&E hydropower provides 20 percent of the power needed to serve customer load. Other key power resources include DWR contracts (28%), Diablo Canyon Nuclear Plant (21%), and Qualifying Facilities (24%), which are cogeneration and renewables.

  PG&E hydropower is a flexible energy resource, and cycles up and down from 300 MW to over 3,000 MW on a daily basis. The system produces an annual average of 11,832 GWh, which ranged from a low of 6,050 GWh to a high of 18,085 GWh between 1975 and 1999 (CPUC 2000).

  PG&E has estimated that their hydropower system avoids annual air emissions of 7.4 million tons of CO2, 2,900 tons of NOx, and 3,400 tons of CO.

- **Sacramento Municipal Utility District (SMUD)**

  SMUD is the nation's sixth largest municipal utility with a peak demand of about 2,800 MW. SMUD's generation capacity includes 688 MW of hydropower and 485 MW of natural gas and renewables. The balance of SMUD's energy is supplied through contract purchases. SMUD's Upper American River Project includes 11 reservoirs, 8 powerhouses, and totals 688 MW. Power production averages 1,800 GWh, and ranges from 800 GWh to 2,800 GWh, depending on hydrologic conditions.

  SMUD's hydropower contributes to system reliability with its flexibility, storage capacity, real time operating reserves and transmission voltage support. It can provide over 650 MW of peaking capacity on hot summer days, and has minute to minute load-following capability.

Variance in Hydroelectricity Production and the "Hydro Swing"

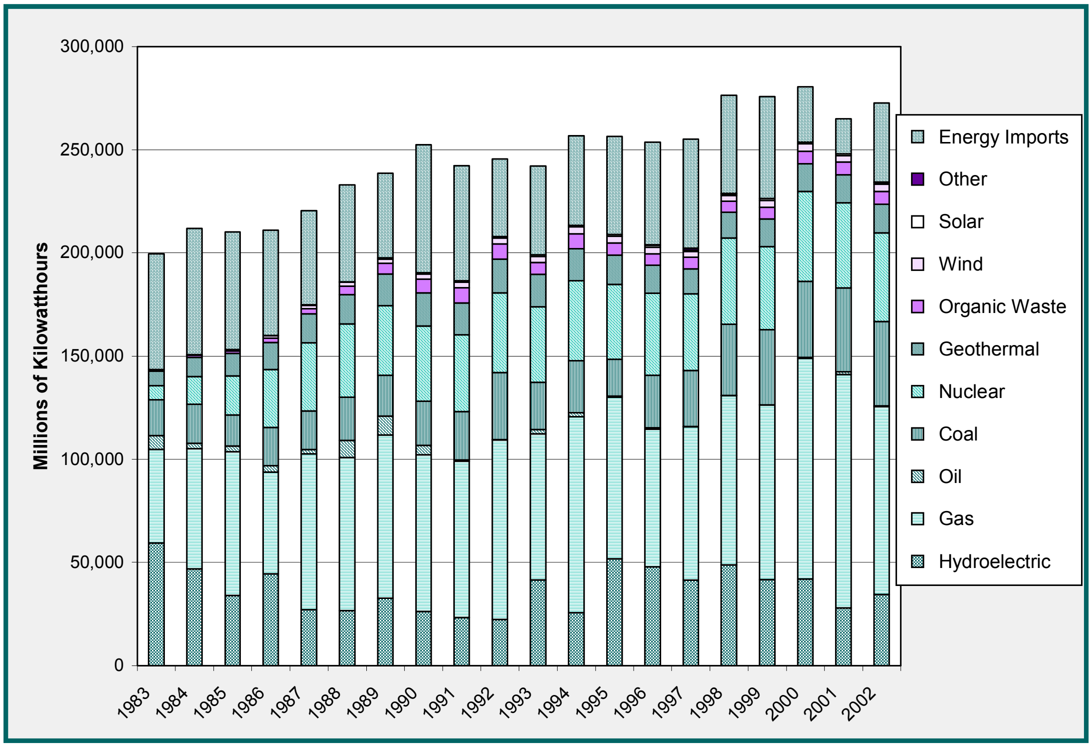
Due to the extreme variance in California hydrologic cycles, hydroelectricity production varies widely from year to year. While hydropower produced an average of 37,345 GWh, or 15 percent of the total electricity used during 1983 to 2001, it varied annually between 9.1 percent and 29 percent. The Western power system has been designed to accommodate this variability. When precipitation runoff is bountiful, hydroelectric generation is used and other generating plants, mostly gas-fired facilities, are idled. When hydroelectric energy generation is low, intermediate and peaking generating plants will make up the difference. **Figure D-3** illustrates the variety of energy sources of California electricity.

This variability of hydro resources has important implications for the overall performance of the state's generating system. Typically, low hydropower production is offset by a combination of increased imports, if available, and increased generation by in-state natural gas power plants. While eight new large combined cycle or cogeneration power plants have come online in recent years, the bulk of the natural gas capacity in the state remains the large steam boiler facilities that were initially developed from mid-1950s into the 1970s by the major utilities. These facilities remain an important part of the overall system, providing both needed capacity for meeting peak demand and intermediate capacity to help meet annual energy requirements, especially during low hydro years.

On a daily basis, hydropower makes important contributions to meeting load following, shoulder peak and peak demands, especially on hot summer days. However, it is thermal generation – primarily natural gas – that provides the bulk of the shoulder and peak demand energy in California. As shown on **Figure D-4**, on a typical hot summer day with peak demand of about 52,000 MW, thermal fired generation provides 55 percent of the capacity while hydro provides about 15 percent.

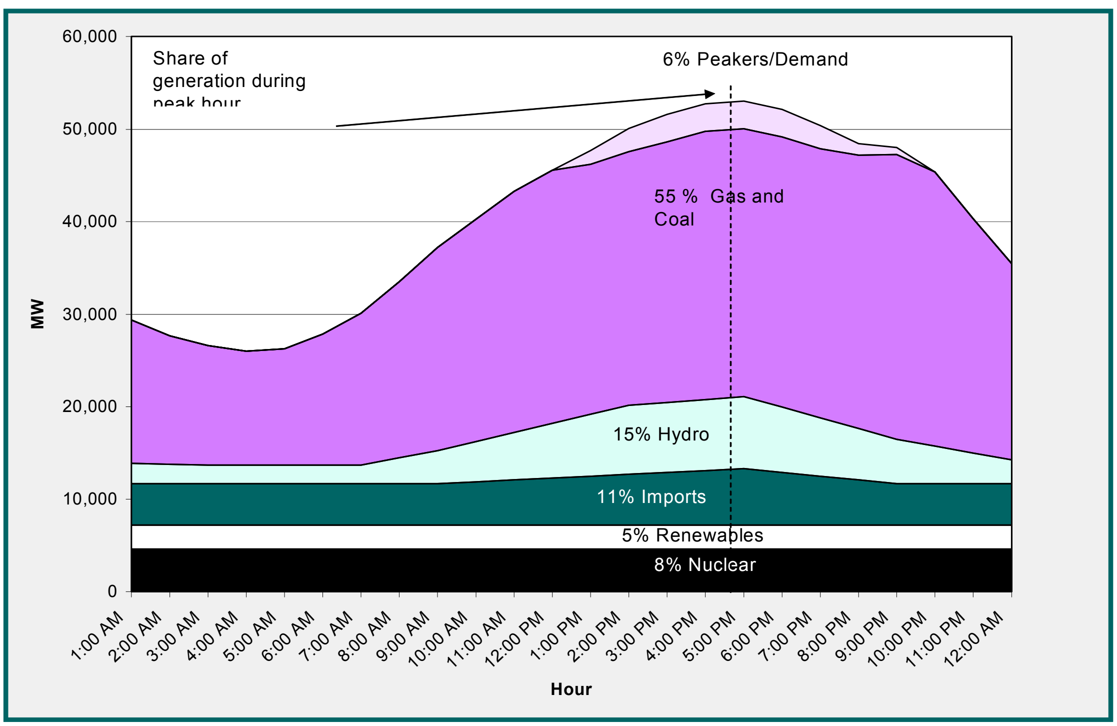
Hydropower is no longer the cornerstone of the state's energy infrastructure that it was in the early and mid-20th Century. Many assumptions about hydropower's unique ability to furnish the bulk of peak demand energy and to rapidly cycle up and down to meet changes in electricity load no longer hold. It is increasingly the natural gas-fired part of the energy system and imports that furnish the bulk of the energy services required to maintain system reliability, as shown in the following charts from the 2003 Environmental Report.

Figure D-3
Sources of California's Electricity



Source: 2003 Environmental Performance Report Figure 2-4.

Figure D-4
Electricity Supply and Demand Profile for Typical Hot Summer Day



Source: 2003 Environmental Performance Report Figure 2-6.

Hydropower Environmental Effects

SB 1389 directs the Energy Commission to report on the environmental performance of the state's electrical generation system. The Energy Commission has no regulatory jurisdiction over hydropower, and therefore does not have the depth of experience and technical knowledge on hydropower environmental issues that agencies have such as the California Department of Fish and Game and State Water Resources Control Board. However, the Energy Commission has expertise in evaluating energy-environment effects because of its jurisdiction over thermal power plants, and is well situated to summarize the broad environmental effects of hydropower, and compare them to the broad environmental effects of other parts of California's electricity generation system.

In the ***2001 Environmental Performance Report*** (2001 EPR), the Energy Commission found that a primary biological impact from California power generation is the loss and alteration of aquatic habitats. Significant damage to aquatic ecosystems continues at hydroelectric facilities and coastal and estuarine sites where thermal power plants use once-through cooling systems. Sixty eight percent of California's current generation portfolio damages aquatic ecosystems.

Sixty one percent of the State's hydropower system (8,619 MW) was built before the 1970s when the major environmental statutes were passed: National Environmental Policy Act, Clean Water Act, Endangered Species Act, California Environmental Quality Act, etc. Due to the preemption of the Federal Power Act and the granting of long-term (30 to 50-year) operations licenses by FERC, many California hydropower projects operate under antiquated regulatory standards that do not meet current State of California environmental regulatory standards, and may not do so until relicensing occurs. This 30 to 50-year license period creates a gap between current mitigation requirements and those that were imposed at the time of the initial license. As a result, almost none of the FERC-regulated hydropower projects in California mitigate their ongoing impacts to the same standards that are required of other energy sector power plants under State of California jurisdiction.

Nearly all California rivers have some level of hydropower development, although the primary purposes of the projects vary. Generally, hydropower operations affect riverine ecosystems by removing water from rivers and streams for power production, changing the natural hydrograph of rivers, changing temperature levels, and blocking fish passage. The daily and seasonal variations in hydropower operations cause rapid variance in water levels and disrupt downstream flows. Fluctuating water levels associated with hydro operations can also affect fish, plants, reptiles, invertebrates, and amphibians. For example, spawning chinook salmon are often stranded on the banks of the Yuba River below Engelbright Dam because of water level fluctuations from peaking power production (DFG 2001).

Very few systems-level environmental assessments of California hydropower effects have been conducted by other agencies or universities. One of the most respected comprehensive assessments was prepared by the US Forest Service and the University of California at Davis. The Sierra Nevada Ecosystem Project (SNEP) found that aquatic and riparian systems are the most altered habitats in the Sierra Nevada, with dams cited as a major degradation factor (UC Davis 1996). The California Public Utilities Commission reviewed PG&E's extensive hydropower system as part of the auction and valuation proceedings, and found that nine projects have instream flow problems and ten have water quality problems (CPUC 2000).

Two-thirds of California's fresh water fish species have been impacted by hydroelectric development (CPUC 2000), and 67 percent of the state's native fish are extinct, endangered or in decline (Mount 1995). Four species of California salmonids are listed as endangered or threatened under the federal Endangered Species Act (winter- and spring-run Chinook salmon, coho salmon, and steelhead trout). Three of California's 11 native trout species are similarly endangered, as is the yellow-legged frog. In summary, California's aquatic ecosystems are severely stressed, as evidenced by the increasing number of once abundant fish and amphibious species that are now in jeopardy of extinction.

The ***2003 Environmental Performance Report*** examined water quality issues in greater detail, and assessed general impacts on California's endangered salmonid species.

Relation of Hydro Development and Salmonid Habitat

The federal register Endangered Species Act listing and critical habitat notices for California populations of spring-run and winter-run Chinook salmon and steelhead trout identify hydropower development and the resulting habitat losses as a causal factor in the population declines of these salmonid species. Other causal factors include water resources development projects, timber harvesting, mining and over-fishing (NMFS 1993, 1994, 1997). Dam construction eliminated 95 percent of the original 6,000 miles of salmonid habitat in the Central Valley (USFWS 1998). A total of 106 populations of salmonids have gone extinct from rivers along western North American (Levin and Schiewe 2001).

A recent phenomenon has been large scale fish kills on salmon bearing rivers. In September 2002, an estimated 33,000 adult Chinook salmon, coho salmon and steelhead returning to spawn in the Klamath and Trinity river system were killed in the lower reaches of the Klamath River. The California Department of Fish and Game attributed the fish kill to a combination of low flows from the Klamath hydro and water supply project, elevated water temperatures, and a large return year class which produced crowding in the lower river reaches. These factors created conditions ripe for a rapid outbreak of bacterial pathogens, which were the lethal factor (CDFG 2003).

Large dams on major tributaries to the Sacramento and San Joaquin Rivers and the Sacramento/San Joaquin Delta block anadromous fish access to the upper reaches of their respective watersheds. For example, endangered spring-run Chinook salmon were once found in 22 major rivers and streams throughout the Sacramento – San Joaquin River drainages; from McCloud River in Shasta County to the Kings River in Fresno County. Spring-run Chinook salmon have since been extirpated from their entire southern San Joaquin River range, and from their entire northern range on the upper Sacramento and Pit Rivers north of Shasta Dam. Wild populations are now found only in the lower reaches of the Feather and Yuba Rivers, and in seven creeks feeding the mid-Sacramento River (DFG 1998, cited by DWR in CEC Hydro Workshop).

For California's winter-run Chinook salmon, population levels decreased from a range of 50,000 to over 100,000 adult fish in the late 1960s to runs of 2,000 to 3,000 adult fish in the 1980s. The population decreased another 75 percent in the early 1990s to runs of 300 to 500 adult fish, which prompted the National Marine Fisheries Service to take emergency regulatory action and designate the species as "endangered" rather than "threatened" (NMFS 1994).

Because most hydropower development projects in California were not required to construct fish bypass facilities (screens, ladders or other provisions for bypassing flows during powerhouse shutdowns), fish movement to historic spawning areas was blocked (NMFS 1996). For example, all the facilities in the North Coast Region block migrating salmon and steelhead.

Table D-2 shows the distribution of California hydropower and the relation to historic salmonid habitats. The greatest number of hydropower facilities (defined as a turbine unit) have been constructed in the Sacramento River watershed region (85 facilities), followed by the San Joaquin River watershed region (56). A majority of the hydropower facilities potentially impact sensitive species and three regions (North Coast, Sacramento River, San Joaquin River) have facilities that affect migrating salmon and steelhead.

Table D-2
Distribution of California Hydro Facilities with Potential for Impacts to Anadromous Fish

Watershed Region	No. of Utility-Owned Hydro Generation Units	% of Total Utility-Owned Hydro Facilities	Main River Systems	% Facilities within Region with Potential for Salmon or Steelhead
Sacramento River	85	36.2%	Sacramento, American, Bear, Pit, McCloud, Feather, Yuba	24.7%
San Joaquin	56	23.8%	San Joaquin, Merced, Mokelumne, Tuolumne, Stanislaus, Calaveras	19.6%
Colorado River	25	10.6%	Colorado	0
South Lahontan	25	10.6%	Owens	0
South Coast	16	6.8%	Ventura, Santa Ana, San Gabriel	0
Tulare Lake	15	6.4%	Kern, Kings, Kaweah	0
North Coast	11	4.7%	Klamath, Russian, Trinity	100%
North Lahontan	2	0.85%	Truckee	0

*Number of utility owned hydro facilities included in MarketSym model.

Reservoir Inundation of Habitats

The Energy Commission has calculated the acreage of land used by each major energy resource in California, and the ratio of acres needed to support a megawatt of electricity capacity. Hydropower has inundated over 250,000 acres of land for reservoir development, and requires about 20 acres of land per megawatt of capacity. Waste to energy plants and wind farms also require large amounts of land per megawatt, at 12 acres per megawatt and 6 acres per megawatt respectively. Reservoirs inundate aquatic riverine, riparian and upland habitats, although these habitat acreages have not been calculated. Dams have contributed to the overall loss of 89 percent of California's riparian habitat (Ketibah 1994). Reservoirs can provide habitat for different assemblages of wildlife and fish species (2003 EPR, Figure III-15).

On the benefits side, dams provide important recreation, water supply and flood control benefits. A full accounting of the many non-energy public interest benefits created by dams and hydropower dams is beyond the scope of this paper.

Water Quality Issues

The key finding for hydropower-related water quality issues in the 2003 Environmental Performance Report is that only nine of 119 FERC-licensed projects in California meet (or will soon meet) current state water quality standards as specified in the water basin plans and as certified by the State Water Resources Control Board under Section 401 of the Clean Water Act.

As reported in the 2003 EPR, the key water quality parameters for hydropower are temperature, flow volume, suspended solids and dissolved oxygen levels. Cold water fish such as trout and salmon require the right balance of temperature, flow volume and oxygen to maintain viable habitat conditions. Cold water fish require water temperatures of 20 degrees Centigrade (68 degrees Fahrenheit) or colder for most life stages. Water temperatures in the river reaches from which water is removed for power generation purposes (bypass reaches) often exceed those levels and are lethal to cold water fishes (US EPA 2003). Water that passes through hydroelectric turbines is classified as a "waste discharge" under the federal Clean Water Act. The California State Water Resources Control Board regulates such waste discharges through Section 401 of the CWA, and sets water quality standards to protect the beneficial uses of water in California.

FERC hydropower licenses are issued for long time periods of 30 to 50 years. The original licenses generally contained no provisions to monitor water quality and aquatic biological conditions and had no provision to change operational practices in response to new scientific understandings of hydroelectric impacts. Rivers were treated as linear water conveyance systems, as opposed to complex, dynamic ecological and physical systems. In accordance with the scientific thinking from the mid-20th century, FERC generally set instream flow levels and release schedules at low, static levels intended to optimize power production from each stream and river segment (SWRCB 2003 – CEC Hydro Workshop Presentation).

Under the Federal Power Act, a FERC project license incorporates the regulatory standards that were in place when the license was issued. This means that the many older California hydropower projects conform with the Federal Power Act, but do not conform to current state regulatory standards or to other federal Clean Water Act or Endangered Species Act standards. As of 2003, only a small portion of California's hydropower system meets current state water quality standards. Six of 119 FERC-licensed projects have 401 CWA certification from the State Water Board, and three more are nearly complete. These nine projects total 275.3 MW.

State Water Resources Control Board and California Department of Fish and Game Work on Hydro Relicensing

The following section summarizes the key points presented by the California State Water Resources Control Board (SWB) and California Department of Fish and Game (DFG) during their presentation on hydro relicensing at the June 5 Hydro Workshop.
The SWB's mission is to preserve and enhance the quality of California's water resources and ensure their proper allocation and efficient use for the benefit of present and future generations. The SWB is charged with balancing society's and nature's needs for water by allocating rights to appropriate surface water. They adjudicate disputes over rights to water, and establish the water quality standards needed to safeguard the beneficial uses of water, which include water supply, agricultural supply, recreation, groundwater recharge, power generation, cold freshwater habitat, wildlife habitat and navigation. The SWB administers the Porter Cologne Act and delegated Clean Water Act authorities, among others.

DFG's mission is to manage California's diverse fish, wildlife and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. DFG is the Trustee Agency for fish and wildlife resources in California. Fish and wildlife resources are held in trust for the people of the State by and through DFG. DFG has jurisdiction over the conservation, protection and management of fish, wildlife, native plants and habitat necessary for biologically sustainable populations of those species.

Hydroelectric projects affect hundreds of waterways throughout California. Forty-six FERC-licensed projects will undergo relicensing between 1997 and 2016. Both agencies have principal roles on behalf of the state during FERC relicensing of hydroelectric projects. Activities include developing and reviewing study design, field studies and study results, commenting on NEPA and CEQA documents, preparing Federal Power Act 10(j) recommendations (DFG), preparing Clean Water Act Section 401 Certification (SWB), and developing long-term monitoring and reporting plans. FERC licensing is a labor-intensive process.

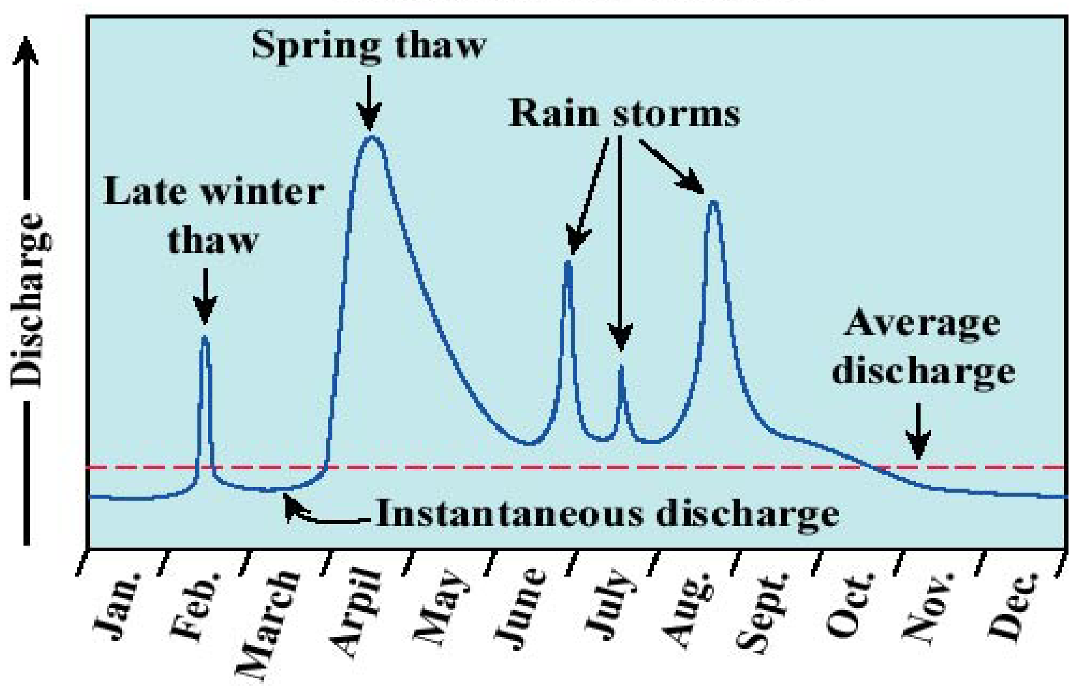
The State Water Board's Water Quality Certification program regulates any applicant for a federal license or permit that may result in any discharge into navigable waters. The SWB issues 401 certifications with mandatory conditions that FERC must include in the license without change. The 401 certifications include monitoring programs to ensure compliance with the conditions of the certification.

Under Section 10(j) of the Federal Power Act, DFG, as the California state fish and wildlife agency, makes recommendations to FERC to adequately and equitably protect, mitigate damages to and enhance fish and wildlife affected by the hydroelectric project. FERC must adopt DFG's recommendations unless it makes a finding that adoption of such recommendations is inconsistent with the purposes of the Federal Power Act.

During relicensing, both agencies work to understand the hydrology of the river system affected by hydropower operations. Securing sufficient hydrologic data for impaired and unimpaired flows, and reservoir levels, is a chronic issue. Both agencies work to develop flow recommendations that will protect instream biological resources and recreational uses. Understanding the effects of hydro peaking operations is important, and balancing peaking operations with run of the river characteristics is challenging. Water quality issues include identifying historic background conditions, current conditions and developing methods to control water temperatures so that they meet beneficial use standards.
For example, native trout have a narrow band of preferred water temperatures for feeding that range from 60 to 65 degrees F. At 70 degrees trout seek out cold water refugia in tributaries and natural springs. Lethal conditions begin at 80 degrees.

The current goal in relicensing is to re-create as much of the natural hydrograph as possible by establishing flows that maintain riverine ecosystem processes such as channel maintenance, gravel recruitment and maintenance of riparian vegetation corridors. Historically, FERC established flat line flows that optimized power production. As shown in **Figure D-5**, the natural hydrograph of rivers has high levels of variability.

Figure D-5
Hypothetical River Hydrograph



Public Interest Energy Research on Hydropower Environmental Issues

The Energy Commission administers the Public Interest Energy Research (PIER) account and program, which is funded through a small surcharge on customer energy bills. The mission of the PIER Program is to improve the quality of life for California citizens by developing environmentally sound, safe, reliable and affordable electricity services and products. Public interest research includes the full range of research and development activities that advance science and technology not adequately provided by competitive and regulated markets.

PIER's hydropower research objectives are to improve our understanding of the interaction between hydropower operations and California's freshwater ecosystems. The aim of this effort is to reduce the risk to the environment and the hydropower sector through the development of relevant data, models and protocols. Anticipated benefits may include the reduction of hydropower impacts on aquatic species and habitats, reductions in permitting uncertainty through better knowledge of ecological factors, avoiding unnecessary limitations on hydropower generation, and increasing environmentally benign hydropower generation.

The specific hydropower research planning efforts are to: 1) identify gaps in understanding of hydropower and aquatic ecosystems; 2) identify research efforts and priorities; and 3) produce three roadmaps to guide research efforts for fish passage, water quality and instream flows.

PIER has three current hydro-related research projects. The first project is to assess the effects of pulsed and ramped flows on aquatic species and habitats. Rapid cycling up and down of hydropower generation is an important energy attribute, but the resulting fluctuations in water flows create a series of environmental effects that are poorly understood. Such effects include the stranding of downstream migrating salmon fry, washing away of amphibian egg masses and alteration of benthic macro-invertebrate communities.

The other two PIER hydro projects are just beginning. One will address forecast methodologies for snowpack and precipitation runoff in order to improve reservoir management. The other will develop indices of biological integrity for streams and rivers affected by hydropower operations.

PIER has a small hydro feasibility assessment program that is identifying opportunities for small hydro development at existing dams. Adding incremental hydroelectric generation to extant dams avoids creating new environmental damage to rivers and streams. The Department of Energy has identified the potential for 2,500 MW of additional small hydro at extant dams in California [citiation]. PIER is also working to identify feasible low flow, low head, low impact technologies that could be installed to tap the energy potential of California's extensive water conveyance system of aqueducts, canals and ditches. PIER funded development of PowerWheel, a low head water wheel that might be installed in exsiting canals with small vertical drops. The demonstration project revealed mechanical problems, and is being phased out.

Energy and Cost Effects of Relicensing, Operations and Selective Decommissioning Proposals to Restore California Rivers and Fisheries

In this section, the Energy Commission staff presents the results of its own investigations, including consultant's reports, on the energy and cost issues associated with hydropower operations, relicensing, or selective decommissioning. Very little objective summary information on these topics has been produced, which hinders decision-makers' ability to make informed policy decisions.

All non-federal hydropower projects are regulated by FERC, which grants hydropower licenses for 30 to 50-year time periods. In California, there are 119 FERC-licensed projects totaling 11,930 MW. Thirty-seven percent of the California hydropower system (5,000 MW) will be relicensed in California by 2015. The changes in hydroelectricity production and capacity from FERC hydro relicensing are poorly understood and have not yet been assessed in California.

Energy Commission Review of Recent California Relicensing Cases

The Energy Commission contracted with Aspen Environmental Group to review 14 California hydropower projects relicensed since 1992, or that are nearing completion of the relicensing process by the Federal Energy Regulatory Commission. The information for the study was gathered from the publicly available Environmental Assessment documents prepared under the National Environmental Policy Act (NEPA). These 14 projects total 567 MW with an average annual production of 2,804 GWh. Most of the projects are owned by PG&E or Southern California Edison (SCE). Two of the projects are in the 200 MW range, while the rest are considerably smaller. This is typical of the size ranges for California hydropower.

Table D-3
Hydroelectric Relicensing Projects Reviewed

FERC License No.	Date License Issued	Project Name	Licensee	River	Authorized Capacity (MW)
P-137	10/11/01	Mokelumne River	PG&E	Mokelumne River	210.7
P-1061	09/30/92	Phoenix	PG&E	South Fork Stanislaus River	1.8
P-1333	12/30/93	Tule River	PG&E	North & Middle Forks Tule River	6.4
P-1354	05/01/39*	Crane Valley	PG&E	Willow Creek North Fork	20.98
P-1388	02/04/97	Lee Vining	SCE	Lee Vining Creek	11.3
P-1389	02/04/97	Rush Creek	SCE	Rush Creek	8.4
P-1390	03/03/99	Lundy	SCE	Mill Creek	3.0
P-1394	07/19/94	Bishop Creek	SCE	Bishop Creek	26.3
P-1403	02/11/93	Narrows	PG&E	Yuba River	12.0
P-1930	06/16/98	Kern River No. 1	SCE	Kern River	26.3
P-1932	07/21/47*	Lytle Creek	SCE	Lytle Creek	0.45
P-1933	08/09/46*	Santa Ana No. 1 & 2	SCE	Santa Ana River	4.0
P-1962	10/24/01	Rock Creek – Cresta	PG&E	Feather River	196.0
P-2290	12/24/96	Kern River No. 3	SCE	Kern River	40.2

*License expired – license re-issued on annual basis while FERC reviews case.

FERC relicensing provides the primary opportunity during the 30 to 50-year license period to modify project facilities and operations to meet current environmental standards. Based on the input from state and federal fisheries, wildlife and water quality agencies, FERC develops Protection, Mitigation and Enhancement Measures (PM&E's). Such measures range from changing project operations by changing instream flows, flow release schedules, or ramping rates, to modifying physical features such as installing diversion screens or fish ladders. Many of these changes result in reductions in electricity production.

As shown in **Table D-4**, the projected energy changes from the FERC relicensing (change from old license to projected changes under new license conditions) totaled an average annual decrease of 147 GWh (2,804 GWh to 2,657 GWh), for a 5.26 percent energy production decrease. In the context of average annual hydropower generation of 37,345 GWh, and annual average electricity consumption of 275,000 GWh, this is a very small change.

These energy changes are modestly higher that the range identified by FERC, which reviewed 246 relicensing cases between 1986 and 2001. FERC data show that on average nationally, relicensing results in a 1.6 percent energy production decrease (FERC 2001). The Energy Commission staff's review of energy changes from recent FERC relicensing cases in California does not distinguish baseload production versus peaking reserve production, nor does it consider the range of production changes for dry to wet hydrologic years. Such factors would provide for a more complete assessment.

Table D-4
Production Changes Resulting From Relicensing

FERC License No.	Project Name	Licensee	Pre-Relicense Production (GWh)	Post-Relicense (GWh)	Change in GWh (%)
P-137	Mokelumne River	PG&E	1103.1	1062	-3.7%
P-1061	Phoenix	PG&E	13	13	0%
P-1333	Tule River	PG&E	28.4	28.7	1.1%
P-1354	Crane Valley	PG&E	100.5	99.78	-0.7%
P-1388	Lee Vining	SCE	29	28.94	-0.2%
P-1389	Rush Creek	SCE	49	49	0%
P-1390	Lundy	SCE	9.3	8.32	-10.5%
P-1394	Bishop Creek	SCE	164	148.5	-9.5%
P-1403	Narrows	PG&E	51.2	42.9 *	-16.2%
P-1930	Kern River No. 1	SCE	178.6	178.6	0%
P-1932	Lytle Creek	SCE	3.73	3.05	-18.2%
P-1933	Santa Ana No. 1 & 3	SCE	25.1	22.4	-10.7%
P-1962	Rock Creek – Cresta	PG&E	864	806	-6.7%
P-2290	Kern River No. 3	SCE	186	166	-10.7%
		Totals	2804.93	2657.19	-5.26%

Five producers chose to increase the capacity of the hydro turbines during the relicensing. This is often done during relicensing to take advantage of the permitting process. The combined pre-relicensing capacity for the five projects was 290 MW. The capacity increases totaled 9 MW, or a 3.6 percent increase over the initial 290 MW reviewed in the study. Again, this modest increase is comparable to FERC's findings, which identified an average installed capacity increase of 4.06 percent in other states.

Hydropower Economics and Relicensing Effects

As with the energy effects of relicensing, the economics of hydropower operations and relicensing are little studied and poorly understood. In contrast, the economics of thermal power plant development, operations and environmental compliance are widely studied and relatively transparent. The Energy Commission has begun an initial inquiry into California hydropower economics by contracting with energy economist Dr. Richard McCann of M.Cubed. This section summarizes the preliminary investigations of M.Cubed and Kessler & Associates.

The 26 FERC-licensed projects reviewed in the study operate within the ISO Control Area and are either in the relicensing process or will soon enter it. The analysis is limited to projects owned and controlled by four utilities - PG&E, SCE, California Department of Water Resources (CDWR) and the Sacramento Municipal Utility District (SMUD) because the most complete data is available from these utilities. These projects comprise the vast majority of larger projects up for relicensing in California over the next decade.

Table D-5 shows the average revenues per megawatt-hour (MWh) generated for each FERC Project.[1] A significant factor in a project's revenues is whether it has reservoir pondage to store and regulate flow releases, and whether it has automatic generation control (AGC) to facilitate provision of system regulation and spinning reserves. Projects with pondage and AGC can provide peaking power to the ancillary services market, which significantly influences resulting revenues. Run of river facilities are those that do not have significant storage and do not vary electricity output, except as related to natural changes in river flows. For run of river facilities, which do not sell ancillary services, the average annual revenues were $30 to $35 per MWh or $150 to $180 per kilowatt-year (KW-Year). For projects that can provide ancillary services, these sales can add $10 to $35 per MWh or $30 to $200 per KW-Year. For example, the Spring Gap-Stansilaus Project, which has AGC and a small flow relative to turbine capacity, collects 64 percent of its revenues through ancillary service sales.

A more detailed economic investigation would include additional consideration of operations and maintenance costs, delineated between fixed and variable components, capital investment for both the existing structures and any new ones required from relicensing, and the financial structure for recovering those costs (*e.g.*, debt and equity shares and rates).

[1] The revenues and generation from all of the units identified in the ISO database for a particular FERC Project were aggregated. The ISO does not distinguish the output from individual units in the SCE Big Creek Project, so the values shown are the average across the entire set of projects.

Table D-5
Comparison of Hydro Plant O&M Costs and Revenues

FERC #	Project Name	Owner	Capacity MW	O&M $/MWh	Revenues $/MWh
2687	Pit No 1	PG&E	60.0	$4.49	$30.61
233	Pit 3-4-5	PG&E	317.0	$2.29	$29.39
2106	McCloud-Pit	PG&E	340.5	$2.55	$72.39
606	Kilarc – Cow Creek	PG&E	4.4	$13.01	$30.39
803	De Sabla	PG&E	26.7	$12.73	$31.58
2661	Hat Creek Nos. 1 & 2	PG&E	20.0	$5.35	$27.31
1962	Rock Creek – Cresta	PG&E	180.0	$4.43	$35.42
2105	Upper North Fork Feather River	PG&E	342.6	$4.05	$52.01
2107	Poe	PG&E	142.8	$2.51	$44.00
2155	Chili Bar	PG&E	7.0	$14.71	$34.02
137	Mokelumne	PG&E	217.2	$7.57	$43.19
2130	Spring Gap- Stanislaus	PG&E	87.9	$5.52	$80.92
178	Kern Canyon	PG&E	11.5	$10.02	$34.32
2175	Big Creek Nos. 1 & 2	SCE	150.2	$6.82	*$45.11*
67	Big Creek Nos. 2a, 8 & Eastwood	SCE	373.3	$5.08	*$45.11*
120	Big Creek No 3	SCE	165.7	$4.47	*$45.11*
2017	Big Creek No 4	SCE	98.8	$3.71	*$45.11*
2085	Mammoth Pool	SCE	180.9	$3.89	*$45.11*
2174	Portal	SCE	10.8	$5.32	*$45.11*
2086	Vermillion Valley	SCE	0.0	NA	NA
372	Lower Tule	SCE	2.5	$27.40	$30.17
382	Borel	SCE	12.0	$13.37	$34.20
344	San Gorgonio	SCE	2.3	NA	NA
2198	Santa Ana 3	SCE	1.2	$146.99	NA
2100	Feather River/Oroville	CDWR	762.9	NA	$45.39
2101	Upper American River	SMUD	641.0	NA	NA

As a converse to power revenues, plant operators incur O&M costs. The values shown in **Table D-5** were compiled from utilities' FERC Form 1 data. These costs were not disaggregated into variable and fixed components, but generally these costs do not vary with plant output. The O&M costs are distributed bimodally. For projects larger than 30 MW, or those that are hydrologically-linked into a coordinated series of projects within a single watershed projects, these costs range from $2 to $7 per MWh. The net margins range from $20 to $75 per MWh for these projects. On the other hand, for smaller, isolated projects less than 30 MW, these costs range from $10 to $15 per MWh. Given that these smaller projects tend to be run-of-river and have average revenues of $30 to $35 per MWh, the net margins appear to be substantially smaller than for the larger projects. These smaller projects may not be financially viable based solely on power revenues, although this analysis does not account for the fact that many California hydropower projects are fully depreciated.

Other generating technologies typically have higher O&M costs than hydropower, often driven by fuel consumption costs. For example, based on analysis presented in the Commission's Integrated Energy Policy Report, a natural-gas-fired combined-cycle power plant costs $40 per MWh to operate, a wind-power plant costs about $18 per MWh, and a flash geothermal plant about $11 per MWh.

Hydro plant owners incur significant costs to relicense facilities. One key question is whether these costs threaten the financial viability of ownership of these plants. **Table D-6** compares the relicensing costs to the net margins calculated from the data presented in **Table D-5**. The calculation of the Net Margin per KW-Year is the total annual revenues minus the O&M costs shown in **Table D-5** divided by the project generation capacity, which can be use to compare against fixed annual costs. The relicensing costs are shown in terms of dollars per KW-Year by applying an annual fixed charge rate of 13.05 percent to the one-time, up front relicensing costs gathered from utility documents.[2]

[2] The 13.05% fixed charge rate is derived from the Cost of Generation models developed for new investor-owned utility hydro projects presented in the Integrated Energy Policy Report. Note that the costs for the Rock Creek-Cresta and Mokelumne projects are shown in $/KW-Year because these are annual recurring costs rather than one-time up front costs as incurred by the other projects.

Table D-6
Comparison of Hydro Relicensing Costs and Revenues

FERC #	Project Name	Owner	Capacity MW	Relicensing Cost $/KW-Yr	Net Margin $/KW-Yr
2687	Pit No 1	PG&E	60.0	$6.53	$149.20
233	Pit 3-4-5	PG&E	317.0	$4.03	$166.50
2106	McCloud-Pit	PG&E	340.5	NA	$344.59
606	Kilarc - Cow Creek	PG&E	4.4	$4.88	$122.24
803	De Sabla	PG&E	26.7	NA	$95.28
2661	Hat Creek Nos. 1 & 2	PG&E	20.0	NA	$123.57
1962	*Rock Creek - Cresta ($/KW-Yr)*	PG&E	180.0	*$3.45*	$177.45
2105	Upper North Fork Feather River	PG&E	342.6	$3.28	$180.37
2107	Poe	PG&E	142.8	$3.14	$199.06
2155	Chili Bar	PG&E	7.0	NA	$102.94
137	*Mokelumne ($/KW-Yr)*	PG&E	217.2	*$10.18*	$173.65
2130	Spring Gap-Stanislaus	PG&E	87.9	$6.40	$403.03
178	Kern Canyon	PG&E	11.5	$5.64	$172.80
2175	Big Creek Nos. 1 & 2	SCE	150.2	$4.96	*$155.53*
67	Big Creek Nos 2a,8 & Eastwood	SCE	373.3	$2.39	*$155.53*
120	Big Creek No 3	SCE	165.7	$2.17	*$155.53*
2017	Big Creek No 4	SCE	98.8	NA	*$155.53*
2085	Mammoth Pool	SCE	180.9	$1.92	*$155.53*
2174	Portal	SCE	10.8	$19.54	*$155.53*
2086	Vermillion Valley	SCE	0.0	NA	NA
372	Lower Tule	SCE	2.5	NA	$17.63
382	Borel	SCE	12.0	$22.49	$116.05
344	San Gorgonio	SCE	2.3	NA	NA
2198	Santa Ana 3	SCE	1.2	NA	NA
2100	Feather River/Oroville	CDWR	762.9	NA	$163.38
2101	Upper American River	SMUD	641.0	NA	NA

Relicensing costs appear to range between $2 and $10 per KW-Year for larger or integrated projects. Compared to the net margins available, these costs can be recovered quickly from power revenues in most cases. However, for smaller projects, where net margins may be as low as $15 per KW-Year, these costs can tip the plant into negative cash flow. In these cases, the projects will have to provide other services to justify continued operation under those conditions.

Table D 7 provides three examples of costs, revenues, net margins and estimated payback periods for operators to recoup their relicensing expenditures. PG&E's Upper North Fork Feather River Project is a high capacity, high revenue project. Spring Gap – Stanislous is a medium capacity, high revenue project, while SCE's Borel Project is a low capacity, low revenue project. For the Feather River Project, the payback period for relicensing costs was 0.11 years; for the Spring Gap project, relicensing costs can be recouped in 0.12 years, while for Borel, the recoupment period would go for 1.5 years.

Table D-7
Examples of Net Margins and Relicensing Cost Paypack Calculations

FERC #	Project Name	Owner	Capacity (MW)
2105	**UPPER NORTH FORK FEATHER RIVER**	**PG&E**	**342.6**
	Net Revenues Calculation		
	Gross Revenues	$52.01	/MWh
	O&M Costs	$4.05	/MWh
	Net Revenues / MWh	$47.96	/MWh
	Annual Energy Production	1,633,332	MWh
	Annual Net Revenues	$78.3	million
	Net Margin (1)	$228.63	$/kW-year
	Project Relicensing Cost Recovery		
	Project Relicensing Costs	$3.28	$/kW-Year
	Relicensing Payback Period (2)	0.11	Years
2130	**SPRING GAP-STANISLAUS**	**PG&E**	**87.9**
	Net Revenues Calculation		
	Gross Revenues	$80.92	/MWh
	O&M Costs	$5.52	/MWh
	Net Revenues / MWh	$75.40	/MWh
	Annual Energy Production	469,844	MWh
	Annual Net Revenues	$35.4	Million
	Net Margin (1)	$403.03	$/kW-year
	Project Relicensing Cost Recovery		
	Project Relicensing Costs	$6.40	$/kW-year
	Relicensing Payback Period (2)	0.12	Years
382	**BOREL**	**SCE**	**12.0**
	Net Revenues Calculation		
	Gross Revenues	$34.20	/MWh
	O&M Costs	$13.37	/MWh
	Net Revenues / MWh	$20.82	/MWh
	Annual Energy Production	66,887	MWh
	Annual Net Revenues	$1.4	Million
	Net Margin (1)	$116.05	$/kW-year
	Project Relicensing Cost Recovery		
	Project Relicensing Costs	$22.49	$/kW-year
	Relicensing Payback Period (2)	1.49	Years

(1) The equation for conversion from $/MWh to $/kW-year is:

*$/kW-Year = ($Net Revenues/MWh * Annual MWh Generated) / (MW Capacity * 1000)*

The $/kW-year value is equivalent to an annual amortized revenue stream that can be compared to revenue requirements for recovering capital investments, which are often stated in terms of $/kW or $/kW-year.

(2) Relicensing Cost Payback Period is calculated as the number of years necessary to recover the costs per kW (a total value rather than annualized) from the Net Margin:

Payback Period = (Relicensing $/kW) / (Net Margin/kW-Year)

This calculation does not account for other investment recovery obligations.

Energy Commission Review of Selective Decommissioning Proposals

Restoration of imperiled salmonid fisheries is an environmental policy objective in California. In some instances, removing a dam or power plant dam can provide access to previously inaccessible upriver habitats, and create important restoration benefits. Many of California's 1,222 jurisdictional dams are old and no longer provide the functions they were originally constructed to provide. For example, siltation is a classic reason for dams becoming non-functional.

DWR and CalFED have an active fish passage improvement program that identifies and assesses impediments to fish passage for migratory species like salmon and steelhead trout. DWR Bulletin 250 provides an inventory of such impediments in California. Typical impediments are culverts, dams, non-screened diversions and poorly functioning fish ladders. CalFED is presently assessing six non-power dams and one power dam (Engelbright on the Yuba River) in California for decommissioning for aquatic habitat restoration purposes (DWR June 5 Presentation).

The Energy Commission staff has reviewed three salmon restoration projects that include decommissioning or reoperation of hydroelectric projects: Battle Creek, Trinity River Diversion, and the Klamath Hydroelectric project. In each case, staff reviewed the effects of the energy losses from the proposed full or partial decommissioning. The combined potential annual energy production loss of these three restoration projects total 1,041 GWh, or 2.7 percent of the state's total annual hydroelectricity production 37,345 GWh.

For these projects, staff analyzed changes in energy capacity and production from the perspective of state-wide and regional electricity supply adequacy, reliability and cost of replacement power. Additional site specific analyses would need to be conducted in order to evaluate local reliability and cost impacts in the context of specific proposals for decommissioning portions of these projects. Staff also evaluated replacement power resources. In instances where a CEQA or NEPA analysis is provided, criteria and thresholds for "significant adverse effect" relating to energy are analyzed. Project-level economics have not part of the analyses.

Energy Commission staff assessments on energy losses from potential decommissioning are just one element of the many factors that need to be assessed in a full benefit-cost analysis. Such comprehensive assessments are conducted as part of the California Environmental Quality Act or National Environmental Policy Act reviews undertaken by appropriate state or federal lead agencies. The current Battle Creek Salmon and Steelhead Restoration Project Draft EIS/EIR is an example of a comprehensive review of the benefits and costs of such a proposed partial decommissioning project.

The Energy Commission has statutory responsibility to provide information on electricity supply adequacy and assess risks to the reliability of the State's electricity supply and transmission system (Public Resources Code 25500 *et seq*.) This information is used by the Legislature, Governor's Office, California Public Utilities Commission, Independent System

Operator, and California Power Authority. The methods used to assess hydropower electricity changes are within the suite of methodologies used at the Energy Commission.

Battle Creek Restoration Project

Battle Creek is a perennial cold water stream that is a tributary to the Sacramento River. It provides habitat for federally listed Chinook salmon and steelhead trout. Because it is a spring-fed stream and does not have a water supply or flood control dam in its lower reaches, Battle Creek provides an "extraordinary restoration opportunity." Partial decommissioning of the Battle Creek Hydro Project would provide access to an additional 42 miles of mainstem salmonid habitat, plus six miles of tributary habitat (Bureau of Reclamation, California State Water Resources Control Board 2003).

PG&E's Battle Creek Hydro Project includes six dams and five powerhouses with a total capacity of 36.3 MW. It is a run of the river project with an average annual production of 245.3 GWh.

The Energy Commission reviewed the six-dam removal option, which would cause the loss of 7.2 MW of dependable capacity and 93.84 GWh of electricity production. The Energy Commission found that: 1) power losses were non-significant regionally in terms of system reliability; 2) no significant environmental effects from air emissions would occur from replacement power; and 3) power replacement costs of 5.1 cents / kWh ($51 / MWh).

California has a total of 55,800 MW of generation capacity and another 6,200 MW of capacity in the Southwest owned by California utilities. Between 1998 and 2003, the Energy Commission licensed nearly 14,000 MW of new capacity. Twenty two of these projects totaling 6,986 MW are now operational, and another 1,718 MW permitted by other jurisdictions are also operational. It is within this context that the potential losses of 7 MW or 36 MW from the Battle Creek hydro project are considered to be non-significant.

Trinity River Diversion

The Trinity River Diversion was constructed in 1956 as part of the federal Central Valley Project in order to divert flows from the Trinity River to the Sacramento River basin. The project diverted 74 percent of the Trinity River to the Sacramento, and reduced populations of Chinook salmon by 67 percent, coho salmon by 93 percent, and steelhead trout by 53 percent.

The Trinity River Diversion has four powerhouses with 497 MW capacity, which is about 25 percent of the total CVP 2,070 MW hydropower capacity. On an annual average, the system produces 5,169 GWh of electricity. Unlike the State Water Project, the CVP is a net energy generator, and 72 percent of the CVP hydroelectricity is made available to Power Preference Customers at extremely low rates.

The Department of Interior's preferred alternative, as identified in the Record of Decision signed by Interior Secretary Babbit, is to restore Trinity River flows to 48 percent of historic levels in order to restore salmonid fisheries. According to the FEIS/R, energy reductions from the preferred alternative would reduce hydroelectric capacity by seven MW and average electricity generation by 287 GWh per year. Replacement power would cost $1.25 per MWh more than the CVP power.

Energy and water customers including SMUD, Westlands Water District and the Northern California Power Association sued to enjoin implementation of the decision, partially on the basis that the FEIS/R did not fully examine impacts from the power crisis and effects of the loss of CVP energy on electric grid reliability and the utiltities' ability to serve customers. A federal judge ordered a supplemental environmental assessment be prepared under NEPA to examine the energy issues. A Notice of Intent / Preparation was released in 2002. SMUD withdrew from the lawsuit in April 2003.

Energy Commission staff provided NEPA and CEQA scoping comments to the lead agencies preparing the supplemental assessment in response to the Notice of Intent / Preparation (CEC 2002). Extensive background on the California electricity system and energy crisis were provided, along with a recommendation that such issues be further examined in the supplemental FEIS/R. Key comments included: 1) Loss of 287 GWh would have no measurable effect on system reliability; 2) The Power Crisis was the result of a drought in the Pacific Northwest, market manipulation, and forced outages that removed 7,000 to 15,000 MW of natural gas generation; 3) Conservation measures during the Power Crisis reduced peak demand by 5,570 MW (14%) in June 2001; 4) Substantial amounts of new generation resources were being licensed and constructed; and 5) The $1.25 per MWh price increase for replacement power was reasonable in the context of the extremely low extant prices for Power Preference Customers, and the electricity rate increases approved by the California Public Utilities Commission.

Klamath Relicensing

The Klamath River is a major salmonid river in Northern California that once supported the third largest salmon runs on the West Coast. PacifiCorp and the US Bureau of Reclamation operate a system of water supply dams and powerhouses that includes the Klamath Hydroelectric Project. Water allocation, supply and water quality problems are severe. In autumn 2002 over 30,000 adult salmon returning to spawn were killed in the lower river reaches as a result of low river flows from the project, elevated water temperatures, crowding of fish due to a large return-year class, and ultimately an outbreak of bacterial pathogens (DFG 2003). The lower project dams block fish passage to upper reaches of the mainstem river and a series of tributary streams. As part of the FERC relicensing process, the Resources Agency and State Water Resources Control Board requested that the Energy Commission staff review the energy effects of full or partial decommissioning.

The Klamath Hydro Project includes seven dams and powerhouses with a total dependable capacity of 163 MW and an average annual energy production of 656 GWh. The JC Boyle powerhouse is the largest of the seven with 90 MW capacity. It provides peaking reserve energy because of its storage capacity. The dams are distributed through Oregon and

California. Iron Gate (18 MW) and the Copco 1 & 2 Dams (20 MW and 27 MW) are in California and are the primary impediments to fish passage.
The threshold question posed by the Energy Commission staff in its assessment was to determine if full or partial decommissioning would be a feasible project alternative from an energy perspective under NEPA and CEQA.

Staff assessed potential loss of the project energy from the perspective of PacifiCorps' energy resource planning for its service territory, and from the perspective of the Northwest Planning Council. The NW Power Planning Council is facing declining reserve margins through 2006 and beyond. Because of the small capacity of the Klamath hydro units, staff concluded that removal of these units "will not have a significant reliability impact on a larger regional scale" (Energy Commission 2003).

PacifiCorps serves 1.5 million customers using an annual average of 47,708 GWh of electricity. PacifiCorps has 1,119 MW of hydro capacity, which comprises 6 percent of it self-provided energy. Coal provides the bulk of PacifiCorps' self-provided energy at 86 percent. PacifiCorps buys about 30 percent of the energy needed to meet customer load through long and short-term contracts. The utility states that it will need about 4,000 MW in new resources from demand side management, new generation and supply contracts to meet is customer load and reserve margin requirements.

Energy Commission staff identified a total of 721 MW of new generation or power purchase contracts in the immediate project vicinity, plus another 1,692 MW of proposed generation in the same area.

With full decommissioning, an average of 656 GWh of hydroelectricity would be lost annually. Assuming production costs of $8,000 per GWh ($8 per MWh), total production costs for the energy would be $3.1 million annually. Assuming a cost of replacement energy of $50,000 per GWh, the net foregone generation would total $16.3 million annually.

Energy Commission staff concluded that decommissioning is a feasible alternative from the perspective of impacts to statewide electricity resource adequacy and that replacement energy is available in the near term. Staff recommended in the report that additional project-specific analyses be conducted as part of further evaluation work on potential decommissioning, including an assessment of the power losses on local electric transmission grid reliability.

Interpretation and Findings

Selective decommissioning of low power – high impact hydropower projects is a viable method for restoring anadromous fisheries in California. Removal of a handful of such projects where salmonid habitat still exists could create important restoration benefits without significantly affecting statewide electricity supply reliability goals. Energy is just one of the factors and issues to evaluate when decommissioning is considered. A key public policy issue is to balance the public benefit gains of fisheries restoration with the financial losses to operators of specific hydroelectric projects. The changes considered for the hydro projects assessed by the Energy Commission are very small in the context of California's 55,800 MW of total generation capacity and their removal would have no appreciable effect on statewide system reliability. Re-adjusting the margins of California's hydropower system can create important restoration benefits. However, the specific electricity losses would be borne by specific investor owned or municipal utilities. The ancillary benefits associated with hydropower also need to be identified and assessed.

For assessing the energy effects of decommissioning, the scale of the energy effect needs to be considered and run-of-the-river projects should be distinguished from storage projects with dispatchable energy reserves. Replacement power is available from a broad, diverse, integrated energy network, and the western energy system is designed to accommodate the broad, historic variance in hydroelectricity availability. The broad variance in hydroelectricity generation from annual hydrologic variance is far larger than the energy production changes assessed for possible decommissioning projects.

One to one correlations between hydro power losses and thermal power make-ups are not accurate. In the current integrated energy system, removing several low power hydro turbines does not mean that they need to be replaced with similar value turbines constructed elsewhere. Sufficient capacity reserves are currently available statewide to compensate for the relatively small capacity losses through 2006. However, the effects on local transmission reliability and stability must be analyzed and additional power will be needed in the long run to meet growing demand.

Ultimately, the net benefits of a potential decommissioning proposal must be fully calculated by the lead agencies. Changes or losses in energy production are just one of the factors to be considered.

Assessing Avoided Air Emissions from Hydroelectricity

Hydropower does not produce air emissions. Given California's poor air quality and concerns about greenhouse gasses, this is an important attribute. However, the relationship between the use of a power resource that does not produce air emissions and benefits to air quality from avoided emissions are poorly understood.

In its comment letter to the Energy Commission on the 2003 Staff Draft of the Environmental Performance Report, PG&E expressed concern that reducing generation from hydroelectric facilities "will invariably translate into an increase in the generation of electric energy at fossil-fired electric plants." PG&E stated further that operation of their 3,896 MW hydropower system "makes it possible to avoid annual emissions of 7.4 million tons of carbon dioxide, 2,900 tons of nitrogen oxide, 3,400 tons of carbon monoxide" (PG&E 2003). While these numbers, presumably based on the general non-hydro emission profile, provide a reasonable first cut estimate of the average annual effect on air emissions from operation of PG&E's hydro system, the actual effect will be highly variable and difficult to predict. Hydroelectric generation varies year-to-year and season-to-season due to variation in precipitation and competing water uses.

Reductions in generation from the hydro system, whether from decommissioning or operational changes required under relicensing or if global climate change affects precipitation patterns, could result in an increase in the use of the fossil-fuel plants to make up for reduced hydro generation. Predicting the air emission or other results of making up for the lost hydro generation is extremely difficult. Since electricity “displacement” is difficult to quantify much less enforce in today’s competitive electricity market, replacement generation for lost hydro, with a variety of environmental discharges, is likely to occur across the WECC. Impacts will depend on the ambient environmental setting where the discharges occur. Air emissions do not correlate directly to adverse impacts, and suggesting that avoiding air emissions is beneficial without describing the impacts from hydro would be incomplete.

Comparing Retirements of Thermal and Hydro Units

The hydropower industry and FERC express concern about the loss of hydropower generation and capacity through relicensing or decommissioning. Such concerns are a factor in current Congressional and FERC efforts to reform the hydropower licensing process. Hydropower projects are rarely retired. Two national exceptions are the decommissioning of the Keswick project in New England and the Elwa project in Washington State, both of which were low power projects whose removal created marked fisheries restoration benefits.

California’s hydropower system includes many old, low power generation units. As discussed earlier, 8,619 MW were constructed prior to the 1970s. Few, if any, of the 119 FERC-licensed projects have been retired.

In contrast, generation units in the thermal and wind sectors have been retired regularly because they are no longer thermally or economically efficient to operate. For example, the 2001 EPR describes the evolution of generation unit construction and retirement at the Moss Landing complex. The first five units totaling 570 MW were built before 1953, and retired in 1995. The 2003 EPR describes recent thermal unit retirements; 950 MW were retired in the past several years from five power stations throughout the state, and an additional 1,098 MW are identified that may be retired over the next several years (**Table D-1**).

One of the key factors in retirement decisions is compliance with state air quality regulations. For example, in the Los Angeles air basin, South Coast Air Quality Management District Rule 2009 requires installation of NOx control technologies on all existing steam boiler units in 2003. Currently, 865 MW of capacity at existing steam boiler units are not yet in compliance with this retrofit rule. Operators will need to determine if it is economic to install the NOx controls. Otherwise, the units may be retired.

A key factor in the continuing reductions of emissions from the thermal power sector is the California Air Resources Board’s ability to set and enforce air quality standards and emissions discharge levels in California air basins. The combination of regulatory requirements for best available control technologies (BACT), offset procurement requirements, and best available retrofit control technologies (BARCT) ensure that new and extant generation units meet current, state-level air emissions standards. Generators that cannot economically operate older units and meet retrofit rules by installing emissions control devices are obligated to substantially reduce hours of operation to meet emissions allowances, or retire the non-compliant units.

Summary and Conclusions

Hydropower is an important element of California's energy resource mix. It is low cost, emissions free and provides ancillary benefits such as recreation, flood control and water supply. The "traditional view" is that hydropower is a clean energy source that provides a critical peaking reserve function for meeting summer electricity demands. This "traditional view" needs to be modified to account for hydropower's impacts, sometimes significant and adverse, to California riverine ecosystems. By reviewing the current environmental science and regulatory situation, examining the full suite of environmental effects, analyzing costs, and assessing the current energy generation and regulatory system in the Western U.S., we can more accurately situate hydropower as one of many valuable energy resources with its own array of impacts and benefits, as have all parts of the state's generation and transmission system.

The 2001 and 2003 Environmental Performance Reports of California's Electrical Generation System find that the continuing impacts to California rivers, streams, fish populations and aquatic ecosystems from hydropower are widespread and can be severe. Current State policies and programs promoting restoration of degraded salmon fisheries, coupled with the large number of pending Federal Energy Regulatory Commission relicensing cases, provide opportunities to improve environmental quality while maintaining the positive energy attributes of hydroelectricity. This view is based upon Energy Commission staff's knowledge of the California hydropower system, assessments of recent relicensing cases and decommissioning proposals in California, as well as an initial assessment of hydropower operations and relicensing costs.

California hydropower has positive and negative attributes. The 2003 EPR documents that all energy resources and elements of the state's energy system cause environmental damage, even the "clean" resources like wind power and hydropower, which have no emissions, or system elements such as electric transmission lines that do not "pollute" in the traditional sense. A future goal is to identify the environmental harm caused by the various pieces of California's energy system, and develop an analytic method that allows for cross-media and cross-sector comparisons.

By adjusting and re-balancing the margins of California's hydropower system, important restoration benefits can be achieved while maintaining the important attributes of hydroelectricity. On a megawatt to megawatt basis, removing a relatively small amount of hydroelectric capacity may provide the greatest return on restoration investment of any energy resource.

Some of the most desirable restoration opportunities are on rivers and streams with high habitat and restoration potential and low power, low value hydroelectric projects. Such opportunities are being identified by state and federal fisheries and water quality agencies.

Energy Commission staff plans to continue to monitor and research issues associated with energy production changes and energy production costs from hydropower relicensing or selective decommissioning. Actions that staff intends to undertake in this area, as staff resources allow, include:

- staff will seek to partner with the CPUC and academic institutions with expertise on utility economics and cost recovery;
- staff plans to make its expertise available to other state agencies during specific relicensing proceedings, as requested, and as staff resources allow;
- staff plans to continue to develop a comprehensive database of California hydropower facilities in order to characterize their energy attributes, operational constraints and general environmental effects;
- staff will continue to work to increase our general knowledge of hydropower system environmental effects so that it is comparable to our understanding of other parts of the electricity supply system; and
- staff expects to continue its research on hydropower environmental effects through the PIER program.

In light of the high number of relicensing cases occurring in California, the Energy Commission staff is concerned that it will be important that all state agencies, including the State Water Resources Control Board and California Department of Fish and Game, have sufficient staff resources for hydro relicensing work.

Recommendations from Other Agencies and Stakeholders

At the at the June 5, 2003 IEPR Workshop on hydropower issues and in written comments on the workshop and the draft Environmental Performance Report, a number of participants offered policy recommendations. These recommendations from the workshop participants are summarized below.

State Water Resources Control Board and California Department of Fish and Game (June 5 Hydro Workshop)

- The Energy Commission, State Water Board and Department of Fish and Game should form a partnership on hydropower issues that would combine the respective strengths and expertise of each agency. The SWB and DFG request that the Energy Commission continue its work on hydropower economics and energy supplies, and hydro environmental research through the PIER program. Both agencies recommend that the Energy Commission continue to apply its expertise to relicensing, decommissioning and other hydropower issues.

Sacramento Municipal Utility District (June 5 Hydro Workshop)

- SMUD agrees that the energy losses from the individual decommissioning proposals and relicensing cases is small, but they recommend that the Energy Commission track the changes cumulatively to ensure that significant effects do not occur.

California Hydropower Reform Coalition (Testimony at June 5 Hydro Workshop)

1. Pursuant to Pub. Res. Code § 25219, the Energy Commission and other State agencies should enter into a Memorandum of Understanding (MOU) with FERC, in order to establish general procedures for their coordination and cooperation in future licensing proceedings here. At a minimum, such an MOU should specify how State agencies will participate in FERC's preparation of the environmental document which will serve as the basis for their respective decisions in any given proceeding.

2. The Energy Commission should actively support the implementation of the Integrated Licensing Process (ILP), as described in paragraph 7.1.2, which FERC is scheduled to adopt on July 23, 2003. If, as expected, the ILP is designated as the default process that replaces the existing processes in licensing proceedings after a short transition period, this new rule offers an extraordinary opportunity to reduce the historical disputes between FERC and the State regarding the scope of their respective jurisdictions. As described in the Notice of Proposed Rulemaking, the ILP is intended to permit unprecedented participation of State agencies in FERC's NEPA review. The ILP and MOU described above would tend to mean that any big-ticket dispute with FERC in a given licensing proceeding is limited to the substance of the ultimate decision, not the procedures that were used.

3. Pursuant to FPA Part II and 18 CFR § 385.1301, the Energy Commission and Public Utilities Commission should petition FERC to undertake a joint proceeding as appropriate to address significant problems in the regulation of electricity market or rates that fall within both jurisdictions.

4. Pursuant to Pub. Res. Code § 25219, the Energy Commission should participate in individual relicensing proceedings to provide its technical expertise in support of the State Water Resources Control Board (SWRCB) and California Department of Fish and Game (CDFG). For example, the CEC could improve the record available to all relicensing participants by modeling the hydrologic and generation consequences of alternative flow regimes.

5. The ***Integrated Energy Policy Report*** should include a forecast of the cumulative energy supply consequences of the hydropower relicensing proceedings that will occur during this planning period, including estimated changes in capacity, total energy, peak energy, and the ancillary services. Such a forecast would improve our understanding of such consequences on a systemwide basis.

6. Pursuant to Pub. Res. Code § 25224, the Energy Commission should cooperate with other State agencies (primarily SWRCB and CDFG), FERC, licensees and other stakeholders,

to compile a public database that includes on a current basis all monitoring results related to the environmental impacts of licensed projects.

The Energy Commission should evaluate the feasibility and merits of a comprehensive network for real-time monitoring of the water quality impacts of hydropower projects. At a minimum, the network should monitor temperature and dissolved oxygen at each point of control (storage, diversion, or release) in a given project. It should supplement the compliance monitoring (generally, limited to minimum flow schedules) required by licenses.

7. Pursuant to Pub. Res. Code § 25216.3(a), the Energy Commission should adopt standards that guide the State agencies participating in a given licensing proceeding to support: (A) comprehensive settlement as the basis for a new license and (B) adaptive management in a rigorous form, including measurable objectives, systematic monitoring of testable hypotheses, and modification of minimum flow schedules or other mitigation measures on the basis of such monitoring results.

8. Pursuant to Pub. Res. Code § 25620, and in cooperation with the U.S. Department of Energy's Advanced Hydropower Turbine Systems Program, the Energy Commission should encourage research and development to test turbine designs that would reduce fish entrainment. For example, one such design now under development would function as a stand-alone facility in a river without being fixed in a dam. Similar cooperation would help improve the state of the science of fish passage facilities.

9. The Energy Commission should cooperate with the Public Utilities Commission (PUC) to adopt rates that encourage licensees to invest in capital improvements and undertake operations that exceed minimum requirements under FPA Part I for protection of environmental quality. One ongoing proceeding is PUC OIR 03-03-015 to implement Pub. Res. Code § 454.3, whereby the PUC may offer an increased rate of return for such good works.

CHRC July 14, 2003 Comment Letter on the 2003 Environmental Performance Report

- The benefits of FERC relicensing for improving environmental performance will require sufficient state staff and information in order to participate in FERC or CPUC proceedings.
- The amount of aquatic habitat in rivers and streams affected by California hydropower should be quantified so that partial degradation through dewatering, and full degradation from blockage of salmon and steelhead habitat, and inundation from reservoirs, can be understood.
- The socioeconomic and cultural impacts and benefits of hydropower in California should be examined by the Energy Commission in future Environmental performance Reports.

References

Allan and Flecker. 1993. Allan, J.D. and Flecker, A.S. Biodiversity conservation in running waters. BioScience 43:32-43.

Aspen Environmental Group. 2003. The Effects of FERC Hydroelectric Relicensing on Electrical Generation in California. Prepared under contract to the California Energy Commission. July 2003.

CDFG 1988. California Department of Fish and Game. California's Wildlife, Volume I, Amphibians and Reptiles. State of California, The Resources Agency, Department of Fish and Game. Sacramento, California.

CDFG 2001. California Department of Fish and Game (DFG). "Testimony of Julie Brownbefore the State Water Resources Control Board at the Lower Yuba River Hearings."February, 2001.

CHRC 2003. California Hydropower Reform Coalition. Testimony presented by Richard Roos-Collins at the Energy Commission's June 5, 2003 Hydro Workshop for the Integrated Energy Policy Report.

CHRC 2003. Comments of the California Hydropower Reform Coalition on the California Energy Commission 2003 Environmental Performance Report, Integrated Energy Policy Report. Docket 02-IEP-01.

California Public Utilities Commission (CPUC). 2000. Draft Environmental Impact Report on Pacific Gas and Electric Company's Application for Authorization to Divest Its Hydroelectric Generating Facilities and Assets. Application 99-09-053.November 2000.

DOI / SWRCB 2003. U.S. Department of the Interior, Bureau of Reclamation and California State Water Resources Control Board. 2003. Battle Creek Salmon and Steelhead Restoration Project. Draft Environmental Impact Statement / Environmental Impact Report. 2003.

DWR June 5 Presentation. Presentation by Ted Frink of the California Department of Water Resources Fish Passage Program at the Energy Commission's June 5, 2003 Hydro Workshop for the Integrated Energy Policy Report.

FERC 2001. Federal Energy Regulatory Commission Staff Report on Hydroelectric Licensing Policies, Procedures, and Regulations – Comprehensive Review and Recommendations Pursuant to Section 603 of the Energy Act of 2000.

Ketibah, X. 1994. A Brief History of Riparian Forest in the Central Valley of CCalifornia,"in California Riparian Systems, Ecology, Conservation and Productive Management edited by R. E.Warner and K. M. Hendrix. University of California Press. 1035 pp.

M.Cubed 2003. Hydropower Economics and Relicensing Effects on Costs and Power Production. McCann, Richard Ph.D. and Kessler, John. Draft report Prepared under contract to the California Energy Commission via Aspen Environmental Group. July 2003.

Mount, J.F. 1995. California Rivers and Streams: the conflict between fluvial process and land use. University of California Press. 329 pp.

Moyle et al. 1998. Moyle, Peter, Marchetti, Michael, Baldridge, Jean, and Taylor, Thomas. Fish Health and Diversity: Justifying Flows for a California Stream. Fisheries 23(7):6-15.

Moyle and Davis, 2000. Moyle, Peter, and Davis, L. A list of Freshwater, Anadromous, and Euryhaline Fishes of California. California Fish and Game 86(4):244-258.

NMFS 1993. National Marine Fisheries Service. Designated Critical Habitat; Sacramento River Winter-run Chinook Salmon. Final Rule. Federal Register. Vol. 58, No. 114, page 33212, June 16, 1993.

NMFS 1994. National Marine Fisheries Service. Endangered and Threatened Species; Status of Sacramento River Winter-run Chinook Salmon. Final Rule. Federal Register. Vol. 59, No. 2, page 440, January 4, 1994.

NMFS 1996. National Marine Fisheries Service. Factors for Decline. A Supplement to the Notice of Determination for West Coast Steelhead Under the Endangered Species Act. National Marine Fisheries Service, Protected Species Branch, 525 NE Oregon Street, Suite 500, Portland, Oregon 97232.

NMFS 1997. National Marine Fisheries Service. Endangered and Threatened Species: Listing of Several Evolutionary Significant Units (ESUs) of West Coast Steelhead. Federal Register. Vo. 62, No. 159, page 43937, August 18, 1997.

PG&E 2003. Comments of Pacific Gas and Electric Company on the California Energy Commission 2003 Environmental Performance Report, Integrated Energy Policy Report. Docket 02-IEP-01.

Resources Agency 2002. Comment letter from Secretary for Resources Mary D. Nichols to Energy Commissioner James Boyd, Chairman, Integrated Energy Policy Report Committee. California Resources Agency Comment on the Scope of the California Energy Commission's Integrated Energy Policy Report (Docket No. 02-IEP-01). November 5, 2002.

SWB – DFG June 5 Presentation. Presentation by Jim Canaday of the California State Water Resources Control Board and Nancee Murray of the California Department and Fish and Game at the Energy Commission's June 5, 2003 Hydro Workshop for the Integrated Energy Policy Report.

University of California, Davis (UC Davis). 1996. Status of the Sierra Nevada:Summary of the Sierra Nevada Ecosystem Project Report. Centers for Water and Wildland Resources, University of California. 22 pp.

US EPA, 2003. U.S. Environmental Protection Agency. Water Temperature Guidance to Protect Pacific Northwest Salmon and Trout. April 29, 2003.